

IEEE Guide for the Measurement of Quasi-Static Magnetic and Electric Fields

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Abstract: A listing of possible measurement goals related to characterizing quasi-static magnetic and electric fields and possible methods for their accomplishment is provided.

Keywords: measurement protocols, power frequency, power frequency harmonic fields, quasi-static magnetic and electric fields

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Introduction

(This introduction is not part of IEEE Std 1460-1996, IEEE Guide for the Measurement of Quasi-Static Magnetic and Electric Fields.)

As an aid for groups and individuals interested in developing magnetic and/or electric field measurement protocols, this guide describes different magnetic and electric field measurement methods that can accomplish specific measurement goals. A single measurement approach is not given because the measurement strategies and instrumentation requirements will differ depending on the measurement environment of interest and the goals of a measurement program. For example, the measurement protocols and instrumentation for characterizing electric and magnetic fields from power lines will differ significantly from those for characterizing fields from video display terminals.

Frequent reference is made to a companion document for this guide: IEEE Std 1308-1994, IEEE Recommended Practice for Instrumentation: Specifications for Magnetic Flux Density and Electric Field Strength Meters—10 Hz to 3 kHz. IEEE Std 1308-1994 describes the types of available instrumentation used for measuring quasi-static magnetic and electric fields, their principles of operation, definitions of terminology, calibration procedures, and sources of measurement uncertainty.

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IEEE Guide for the Measurement of Quasi-Static Magnetic and Electric Fields

1. Overview

This guide is divided into six clauses. Clause 1 provides the overview, Clause 2 lists other standards that are useful in applying this guide, and Clause 3 describes the characteristics of quasi-static magnetic and electric fields that are candidates for measurements. The text for Clause 3 is taken from IEEE Std 1308-1994.¹ Clause 4 briefly describes the types of available quasi-static magnetic and electric field measuring instrumentation. Clauses 5 and 6 describe specific measurement goals related to characterizing quasi-static magnetic and electric fields, respectively, and possible measurement methods for their accomplishment. Throughout this guide, the terms "magnetic field" and "magnetic flux density" will be considered synonymous. Annex A provides a listing of bibliographical references cited.

This guide provides a listing of possible measurement goals related to characterizing quasi-static magnetic and electric fields and possible methods for their accomplishment. The fields of interest are typically produced by devices that operate at power frequency and that produce power frequency and power frequency harmonic fields, as well as devices that produce fields that are independent of the power frequency. The listings of possible goals and methods should not be considered as complete because there are many possible goals and methods for their accomplishment. The approach taken in this guide parallels a method described in [B3].²

Descriptions of instrumentation, their principles of operation, definitions of terminology, calibration procedures, and a listing of sources of measurement error are given in IEEE Std 1308-1994 and should be used with this guide. Protocols for measuring magnetic and electric fields near power lines and video display terminals are given in IEEE Std 644-1994 and IEEE Std 1140-1994.

¹Information on references can be found in clause 2.

²The numbers in brackets preceded by the letter B correspond to those of the bibliography in Annex A.

2. References

This guide shall be used in conjunction with the following publications:

IEEE Std 539-1990, IEEE Standard Definitions of Terms Relating to Corona and Field Effects of Overhead Power Lines (ANSI).³

IEEE Std 644-1994, IEEE Standard Procedure for Measurements of Power Frequency Electric and Magnetic Fields from AC Power Lines (ANSI).

IEEE Std 1140-1994, IEEE Standard Procedures for the Measurement of Electric and Magnetic Fields from Video Display Terminals (VDTs) from 5 Hz to 400 kHz (ANSI).

IEEE Std 1308-1994, IEEE Recommended Practice for Instrumentation: Specifications for Magnetic Flux Density and Electric Field Strength Meters—10 Hz to 3 kHz (ANSI).

3. General characteristics of quasi-static magnetic and electric fields

Magnetic and electric fields produced by power lines, appliances, and other electrical equipment may be characterized according to magnitude, frequency, waveform (harmonic content), degree of polarization, spatial variation, and temporal variation.⁴ These characteristics are described briefly because one or more of them may be selected for measurement, and because of their importance in specifying requirements for instrumentation used to measure the fields.

Several of the field parameters may be introduced by considering magnetic fields produced by currents in three-phase power lines. Some of the same parameters are also used to characterize electric fields. In general, the magnetic field at a point in space may be represented as a rotating vector that traces an ellipse for every cycle of the currents in the conductors, as shown schematically in Figure 1 (a) [B10]. The root-mean-square (rms) magnitude and direction of the semi-major axis, given by M in Figure 1 (a), indicates the magnitude and direction of the maximum magnetic field. Similarly, the rms magnitude and direction of the semiminor axis, given by m in Figure 1 (a), describes the minimum magnetic field. Such fields are said to be elliptically polarized.

³IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

⁴This guide does not consider transient temporal variations, i.e., events that are fast compared to the periods of quasi-static magnetic and electric fields under consideration.

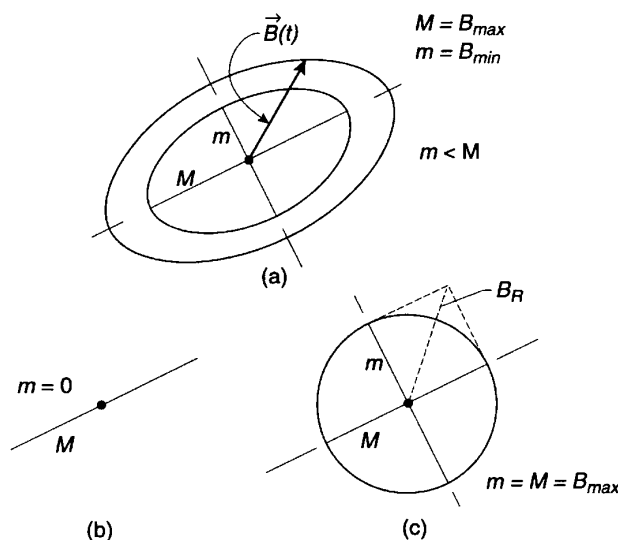


Figure 1— Oscillating and rotating magnetic field quantities for the cases of (a) elliptical $m < M$, (b) linear $m = 0$, and (c) circular polarization $m = M$.

NOTE — The resultant, B_R , and the maximum magnetic field, M , are equal only for the case of linear polarization. The largest difference between the resultant and maximum magnetic field occurs for circular polarization, i.e., B_R exceeds M by 41%.

An often-measured field quantity is the resultant magnetic field, B_R , given by

$$B_R = \sqrt{B_x^2 + B_y^2 + B_z^2} \quad (1)$$

where B_x , B_y , and B_z are the rms values of the three orthogonal field components. The differences between B_R and the maximum magnetic field, M , for different field polarizations are discussed in IEEE Std 1308-1994 and [B20] (see also Figure 1 of this guide).

Because magnetic fields in environments away from power lines also can be produced by multiple current sources that are not necessarily in phase, elliptically polarized magnetic fields can occur in many settings (e.g., homes and work places). Depending on the geometry and currents in the conductors, the degree of magnetic field polarization at a point can vary from linear ($m = 0$) to circular ($m = M$), as shown in Figure 1 (b) and (c). Linearly polarized fields are also referred to as single-phase alternating fields. This discussion of polyphase fields assumes that there are no harmonics in the field. The polarization state of fields with significant harmonic content is more complicated [B24, B32].

Near ground level, the magnitude of the magnetic field from a three-phase transmission line changes slowly as a function of the height of the measurement point above ground. For example, for a typical 500 kV line, the change in the magnetic field magnitude at a height of 1 m above ground level is less than 2% for a 10% change in the measurement height for locations underneath the line. The uniformity increases at more distant points. For locations far from the line, the magnitude of the magnetic field from a single circuit three-phase line, with balanced or nearly balanced currents, decreases approximately as $1/r^2$, where r is the lateral distance from the line (r is assumed to be much greater than the conductor spacing) [B29]. As the net current increases, the decrease in magnetic field magnitude changes from a $1/r^2$ to a $1/r$ dependence [B29, B38].⁵ The magnetic field from balanced double-circuit, three-phase lines with low reactance phasing (i.e., for identical or nearly identical load currents for both circuits) decreases nearly as $1/r^3$ where r is again much larger than conductor spacing. The temporal variations of the magnetic field is a function

⁵The net current is given by the summation over N conductors, $\sum i_n$ where i_n is the current in the n th conductor and is characterized by its phase with respect to current in the other conductors, and its magnitude.